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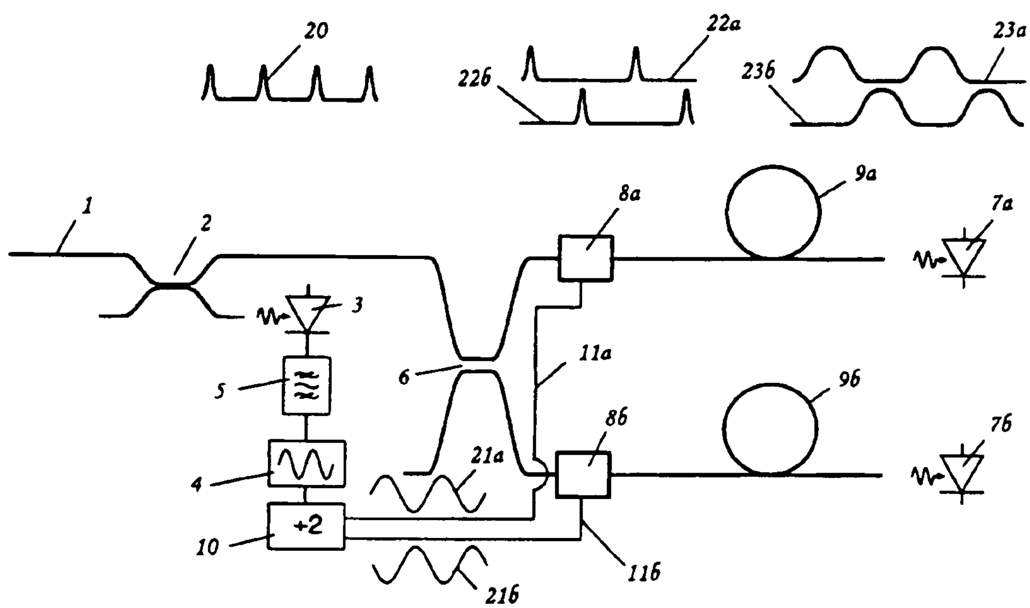

(57) Abstract

At a receiver a 20 Gbit/s soliton bit stream (20) is demultiplexed into two 10 Gbit/s bit streams (22a, 22b) using a 2-way splitter (6), a clock extraction circuit (4), and a pair of polarisation insensitive amplitude modulators (8a, 8b) exhibiting positive chirp. The outputs of the modulators are fed to detectors (7a, 7b) via lengths (9a, 9b) of optical fibre exhibiting normal dispersion thereby producing bit streams (23a, 23b) with increased mark/space ratio and reduced timing jitter.

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METHOD AND APPARATUS FOR CONDITIONING OPTICAL SOLITONS.

Background of the Invention

This invention relates to the conditioning of optical soliton bit streams, and finds particular, but not necessarily exclusive, application in the conditioning of such bit streams preparatory for data detection at a receiver.

One of the factors complicating the detection of data in a soliton bit stream at a receiver is that, on the one hand the mark/space ratio of soliton bits is relatively small in order to avoid soliton/soliton interactions, while on the other hand the timing of the solitons is liable to become contaminated by jitter in their transmission from transmitter to receiver.

Summary Of The Invention

The present invention affords a way of ameliorating these problems.

According to the present invention there is provided a method of conditioning an optical soliton principal bit stream, wherein the bit stream is divided into a plurality of interleaved subsidiary bit streams using optical amplitude modulators, which subsidiary bit streams are transmitted through associated lengths of optical waveguide exhibiting normal chromatic dispersion to said subsidiary bit streams whereby the mark/space ratio of said subsidiary bit streams is increased.

The invention also provides a conditioner of optical solitons that includes a clock extraction circuit, and optical input optically coupled with an n-way optical power splitter that is optically coupled with n lengths of fibre exhibiting chromatic dispersion via n amplitude modulators, wherein the clock extraction circuit has an output connected to a divide-by-n circuit that is adapted to provide, for the n modulators, divide-by-n circuit that

provides a set of n electrical outpoints, one for each modulator, that are interleaved in time with $2\pi/n$ phase separation, each at a rate reciprocal-n times the clock rate provided by the clock extraction circuit is a 2-way splitter and so the divide circuit is a set of n drives interleaved in time, each at a rate reciprocal-n times the clock output of the clock extraction circuit.

In the case of lengths of fibre exhibiting increasing refractive index with increasing light intensity, the chromatic dispersion is preferably normal dispersion so that the two effects assist each other in producing pulse spreading.

Preferably, the modulators exhibit positive chirp. Chirp is a measure of the rate of change of phase with change of light intensity. For the purposes of this specification, positive chirp is defined to mean the condition in which increasing light intensity produces a positive frequency shift (i.e. decrease of refractive index). Preferably that chirp is positive chirp in the case of lengths of fibre exhibiting normal chromatic dispersion , and negative chirp in the case of lengths of fibre exhibiting anomalous chromatic dispersion.

Brief Description Of The Drawing

There follows a description of the conditioning of soliton pulses at the receiver end of an optical soliton transmission system. This conditioning is effected by means of a conditioner which will be described with reference to the accompanying drawing, which is a schematic representation of the conditioner and also depicts waveforms appearing at different locations in the conditioner.

Detailed Description of the Embodiment

Referring to the drawing, at the receiver end of an optical soliton transmission system, the signal is applied to the conditioner on a single mode optical fibre 1. A coupler 2 is employed to extract a small proportion of the optical signal power for clock extraction purposes. This is fed to a detector 3 to provide an electrical signal fed to a clock extraction circuit 4 via a filter 5.

The remainder of the optical signal on fibre 1 is transmitted to a 1 x n optical power splitter 6, in this particular instance the power is split two ways. Each optical output of the splitter is applied to an associated detector 7 via an associated series combination of optical amplitude modulator 8 and length of optical fibre 9 that is normally dispersive to the optical solitons. In the illustrated instance of a 2-way optical power splitter 6, these detectors, modulators and lengths of normally dispersive fibre are respectively designated 7a, 7b, 8a, 8b, 9a and 9b. For a reason explained later, the modulators 8 are preferably modulators exhibiting positive chirp.

The electrical output of the clock extraction circuit 4 is fed to a divide-by-n circuit 10 that provides a set of n electrical outputs 11, one for each modulator 8, that are interleaved in time with $2\pi/n$ phase separation, each at a rate reciprocal-n times the clock rate provided by the clock extraction circuit 6. In this instance the optical power splitter 6 is a 2-way splitter and so the divide circuit 10 is a divide-by-2 circuit having two outputs 11a and 11b.

The particular conditioner described above with reference to the accompanying drawings is designed for a 20 Gbit/s stream of soliton pulses. The electronic timing circuits (not shown) that are employed to perform timing and threshold decisions on the received pulses (i.e. decide between '1's and '0's in each bit period) have narrow usable time windows at 20 Gbit/s (significantly less than a bit period). This makes the error rate particularly sensitive to pulse jitter. The clock extraction circuit 4, n-way splitter 6, modulators 8 and divide-by-n circuit 10, co-operate to form a fast switching optical demultiplexer, and serve to provide a wider timing window (closer to the full width of a bit period).

Optical soliton propagation occurs when intensity-dependent refractive index effects are balanced by dispersion effects, and such a balance requires the dispersion to be anomalous dispersion. The lengths 9 of optical fibre are lengths of fibre exhibiting normal dispersion, and so the solitonic shape of pulses is not preserved in the propagation of such pulses along this fibre, and accordingly there is significant pulse

spreading. This is advantageous because solitons are a small fraction (typically about 20%) of the bit period wide, and pulse arrival may be anywhere within the bit period. To ensure detection of the data, the solitonic pulses first need to be stretched in time to ensure that the stretched pulses will overlap the timing window of the decision circuit. Optical pulse spreading is useful because it makes fast electrical detection less critical. There is an advantage in keeping the receiver chain as simple as possible in order to avoid electrical reflections which can lead to patterning problems.

The use of modulators 8 that exhibit positive chirp is beneficial in reducing timing jitter. Provided that the modulators are driven with generally sinusoidal waveforms, a soliton that arrives early is arriving at a time in which the optical intensity is rising, and therefore that soliton is subject to a positive frequency shift. The pulse then propagates in fibre exhibiting normal dispersion, and so its propagation velocity is smaller than it would have been in the absence of the frequency shift. It is accordingly delayed. Conversely, a soliton that arrives late is subject to a negative frequency shift which serves to increase the propagation velocity, thereby causing the pulse to do some catching up.

Waveform 20 depicts four solitons arriving in four consecutive bit periods at a bit rate of 20 Gbit/s. The clock extract circuit 6 produces a 20 Ghz output which the divide-by-2 circuit 10 converts into two 10 Ghz waveforms 21a and 21b separated in phase by π. Their application to the modulators 8 causes each modulator to gate alternate solitons so as to produce the solitonic pulse waveforms 22a and 22b at the outputs of the two modulators respectively. These pulses are stretched on their propagation through the lengths of fibre 9a and 9b, and arrive at the detectors 7c and 7b with the waveforms 23a and 23b that have a mark/space ratio much closer to 1:1 than that of waveforms 22a and 22b. (No attempt has been made with these waveforms to illustrate the reduction of jitter consequent upon using modulators 8a and 8b exhibiting positive chirp).

Since there are generally liable to be uncertainties regarding the polarisation state of solitons arriving at the receiver, it is generally preferred to employ amplitude modulators 8 that are polarisation insensitive. Amplitude modulators that are substantially polarisation insensitive can be constructed that exploit the Franz-Keldysh effect in a p-i-n ridge waveguide structure in InGaAsP with ridge width and active waveguide layer thicknesses tailored to minimise polarisation dependent loss. As a result of the Franz-Keldysh effect, the optical absorption edge of the device is shifted to longer wavelengths by applying an electric field across the waveguide. In operation, the absorption edge is generally on the short wavelength side of the signal. As the electric field is applied, the signal experiences increasing attenuation, and also an associated refractive index change, such a change being described by the Kramers-Kronig relations between real and imaginary components of refractive index. Accordingly, in the general case, the application of the electric field produces a mix of amplitude and phase modulation. If the InGaAsP composition is such as to provide an absorption edge typically 500nm or more to the short wavelength side of the signal, polarisation independent modulation is predominantly phase modulation with low residual amplitude modulation and low insertion loss. On the other hand, if the InGaAsP composition is such as to provide an absorption edge not more than about 50 nm to the short wavelength side of the signal the insertion loss is significantly greater and the device functions as an amplitude modulator exhibiting negative chirp. Between these extremes the value of the insertion loss is reduced from the high value associated with the small wavelength separation, and, more particularly, the sign of the chirp changes from negative to positive to provide the type of modulator particularly suitable for the present application.

CLAIMS:

1. A method of conditioning an optical soliton principal bit stream, wherein the bit stream is divided into a plurality of interleaved subsidiary bit streams using optical amplitude modulators, which subsidiary bit streams are transmitted through associated lengths of optical waveguide exhibiting chromatic dispersion to said subsidiary bit streams whereby the mark/space ratio of said subsidiary bit streams is increased.

2. A method of conditioning as claimed in claim 1, wherein the lengths of fibre exhibit normal chromatic dispersion.

3. A method of conditioning as claimed in claim 2, wherein said principal bit stream division is effected using optical amplitude modulators that exhibit positive chirp whereby the timing jitter of the bits of the subsidiary bits streams after transmission through said lengths of optical waveguide is reduced in comparison with their timing jitter before transmission through said lengths of optical waveguide.

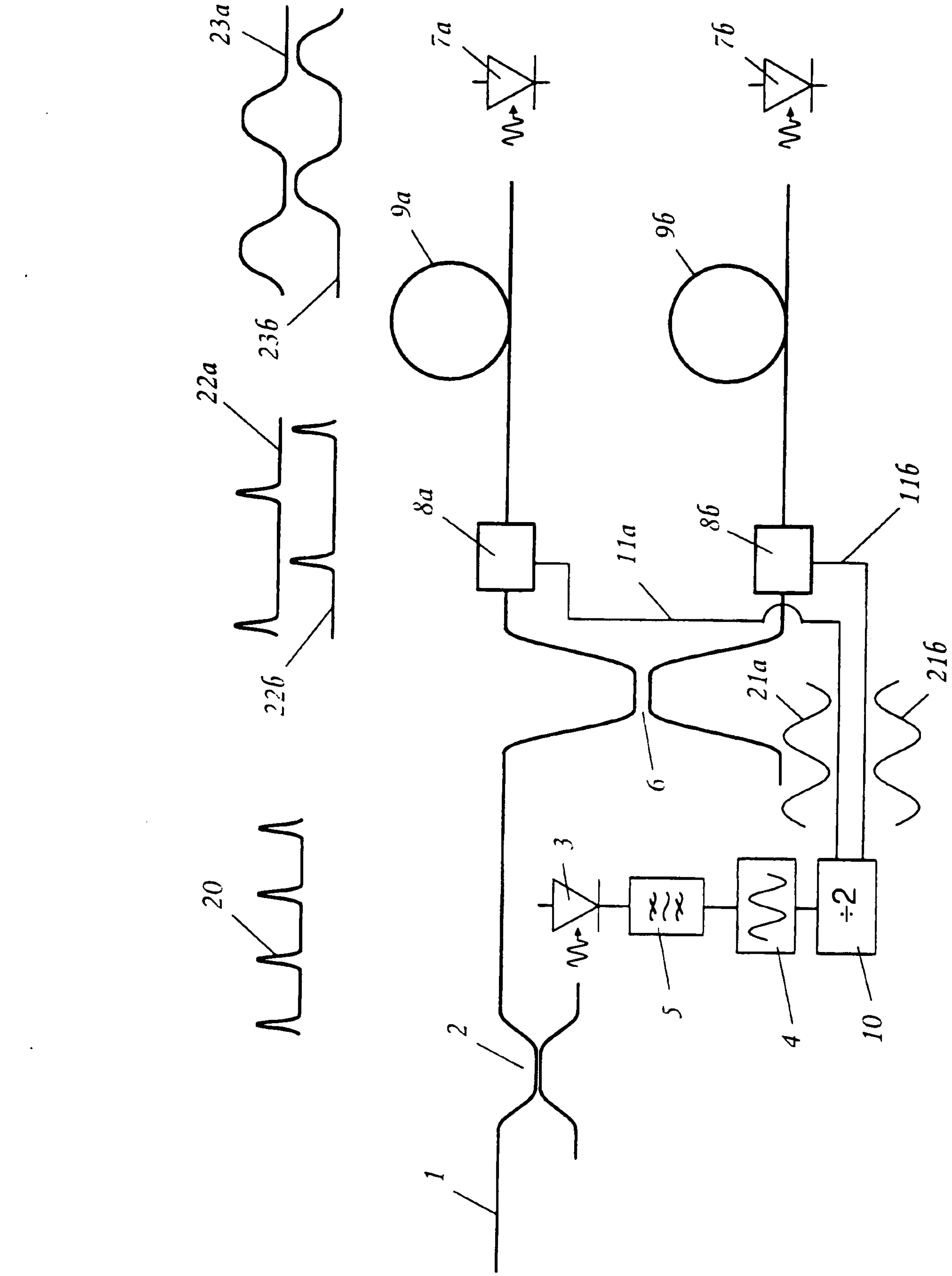
4. A method as claimed in claim 1, 2 or 3, wherein said principal bit stream division is divided into two interleaved subsidiary bit streams.

5. A conditioner of optical solitons that includes a clock extraction circuit (4), and optical input optically coupled with an n-way optical power splitter (6) that is optically coupled with n lengths (9a, 9b) of fibre exhibiting chromatic dispersion via n amplitude modulators (8a, 8b), wherein the clock extraction circuit has an output connected to a divide-by-n circuit (10) that is adapted to provide, for the n modulators, a set of n drives interleaved in time, each at a rate reciprocal-n times the clock output of the clock extraction circuit.

6. A conditioner of optical solitons as claimed in claim 5, wherein the lengths of fibre exhibit normal chromatic dispersion.

7. A conditioner of optical solitons as claimed in claim 6, wherein the n amplitude modulators exhibit positive chirp.

8. A conditioner of optical solitons as claimed in claim 5, 6 or 7 wherein the n-way optical power splitter is a 2-way splitter.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INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/GB 96/00480

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B10/158

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 555 063 (KOKUSAI DENSHIN DENWA) 11 August 1993 see column 7, line 45 - column 8, line 15 see column 8, line 34 - line 38 see column 8, line 56 - column 9, line 15 see figure 6	5,8
Y		1,4
A		2,3,6,7

Y	EP,A,0 609 129 (ALCATEL) 3 August 1994 see column 5, line 5 - line 51 see figure 1	1,4

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 June 1996	18.07.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Williams, M.I.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IEICE TRANSACTIONS ON ELECTRONICS, vol. 78, no. 1, January 1995, TOKYO JP, pages 12-20, XP000495078 SUZUKI ET AL: "Long distance solition transmission up to 20 Gbit/s using alternating amplitude solitions and optical TDM" see page 15, left-hand column, line 1 - right-hand column, line 15 see figure 4 -----	1-8

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

.rmation on patent family members

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